



Final Project Report

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EUROCONTROL; FREQUENTIS; INDRA; THALES.

Abstract

The purpose of the project was to develop a SWIM technical infrastructure, to verify it met the SWIM Technical Specification requirements, and to provide system work packages with necessary software to connect to SWIM for operational validations. The project was also responsible for setting up a SWIM demonstration platform and for organizing periodical demonstrations to expose results of SWIM technical infrastructure developments and improve the SWIM awareness all over the SESAR program.

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Acronyms

Acronym	Definition
ACC	Area Control Centre
ADS-C	Automatic Dependant Surveillance - Contract
AGDLGMS	Air/Ground Datalink Ground Management System
AGSWIM	Air/Ground SWIM
AF	ATM Functionality
AIM	Aeronautical Information Management
AIRM	ATM Information Reference Model
AM	Airspace Management
AMAN	Arrival MANager
AMQP	Advanced Message Queuing Protocol
APOC	Airport Operations Centre
APP	Approach Centre / Control
ATC	Air Traffic Control
ATM	Air Traffic Management
ATSU	Air Traffic Service Unit
B2B	Business to Business
BP	Blue Profile
CFMU	Central Flow Management Unit
CNS	Communication, Navigation and Surveillance
COTS	Commercial Of The Shelf
CTA	Controlled Time of Arrival
CWP	Controller Working Position
DDS	Data Distribution Service
EAD	European AIS Database
ED-133	EUROCAE document ED-133 is the Flight Object Interoperability Specification. It defines the interfaces between two civil ACC's FDP

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	systems.
ENB	Enabler
ER	En Route, En-route
EUROCAE	European Organisation for Civil Aviation Equipment
F2F	Face To Face
FAA	Federal Aviation Administration
FDP	Flight Data Processing
FO	Flight Object
FOC	Flight Operations Centre
FTF	Finalization Task Force
GGSWIM	Ground-Ground SWIM
IBP	Industry Based Platforms
ICD	Interface Control Document
ICOG	Interoperability Consulting Group
INTEROP	Interoperability Requirements
IOP	Interoperability
ISRM	Information Service Reference Model
NFR	Non-functional requirement
NIMS	Network Information Management Systems
NM	Network Manager
NOP	Network OPERations or Network Operations Portal
NOTAM	Notice to Airmen
OI	Operational Improvement (Step)
OFA	Operational Focus Area
OMG	Object Management Group
OTIS	Operational Terminal Information Service
PCP	Pilot Common Project
PENS	Pan-European Network Services

PP	Purple Profile
R&D	Research & Development
RTD	Research & Technological Development
SESAR	Single European Sky ATM Research Programme
SESAR2020	SESAR 2020 Exploratory Research Programme
SJU	SESAR Joint Undertaking
SMGCS	Surface Movement Guidance and Control System
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
SSM	Source Specific Multicast
SWIM	System Wide Information Management
SWIM SUIT FP6	System Wide Information Management Supported by Innovative Technologies
SWIM-TI	SWIM Technical Infrastructure
TAD	Technical Architecture Description
TRL	Technology Readiness Level
TTA	Target Time of Arrival
TS	Technical Specification
UAC	Upper Area Control
UDDI	Universal Description Discovery and Integration
YP	Yellow Profile
VPN	Virtual Private Network
WAN	Wide Area Network
WG	Working Group
WOC	Wing Operation Centre
WP	Work Package
WS	Web Service
WS-Notification	Web Service Notification

XMAN	Cross Border Arrival Management
XML	Extensible Markup Language

1 Project Overview

The SWIM Technical infrastructure provides all the technical services required by ground ATM systems to interoperate through SWIM including SWIM governance means.

The objective of the project was to build and to demonstrate the SWIM technical infrastructure by assembling, configuring and complementing COTS software; as well as to verify the SWIM technical infrastructure requirements before delivery among others to system WPs and to connect to SWIM for operational validations.

The project also contributed to additional programme level activities by providing technical expertise for the preparation of SESAR solution pack related to Initial ground-ground interoperability (#28), contributing to the definition of the SWIM compliance criteria, participation to SWIM compliance assessment of various validation exercises.

The project contributed to the raise of SWIM awareness within the SESAR program by organising periodic SWIM demonstrations including series of workshops, and outside of the program by participating to the SWIM demonstration at the ATM World Congress 2013 in Madrid, and leading two major demonstrations at the SWIM Global Demonstration 2016 in Rome [46].

The project objective was clearly not to develop the entire SWIM technical infrastructure. It favoured extensive use of widely deployed products (COTS or open sources) to build up a technical infrastructure focusing on capabilities required for SESAR validation exercises and demonstrations.

1.1 Project progress and contribution to the Master Plan

The project has started early in the SESAR programme before the 'SWIM Design' and the 'Interface specifications and Services Technical requirements' projects. It had consequently the responsibility to first deliver an architecture definition together with the requirements for the Ground/Ground SWIM Technical Infrastructure[12]).

The project has first analysed prior work from the 'SWIM SUIT FP6 project follow-up and alignment' project that has assessed results from SWIM-SUIT, a 6th Framework European Commission RTD project that ran from 2007 to 2010. It then analysed work from 'Identification of Technology and services options', 'SWIM Security solutions', and 'SWIM technical supervision' projects. Furthermore, the project succeeded in defining requirements covering Interoperability between ATCs and the description of the communications for the NM B2B and EAD B2B. This was achieved with coordination with 'Flight Object IOP System Requirement & Validation' project and 'Information Management' Work Package.

Industry partners in the project have then developed SWIM-TI V1.X prototypes relying on open standards and supported by a combination of COTS or open sources and internal developments when appropriate. The project has delivered the ATC-to-ATC prototypes for use in IOP validation exercises.

Once the 'SWIM Design' and 'Interface specifications and Services Technical requirements' projects have been started a top-down approach has been used within the SWIM Work Package. The project relied then on the available SWIM TS and TAD and SWIM profiles versions to define, develop and verify technical infrastructures driven by the needs of SESAR validation exercises and SWIM demonstrations.

Feedback from first validation exercise stressed the need for tighter coordination with CNS Work Package to take into account existing network infrastructure and defined SWIM-level network requirements. The project took part in the SJU-PENS Technical Co-ordination Group F2F meeting to define the SESAR-VPN needs for the success of SESAR validation exercises over PENS.

The project's verification activities were performed in a dedicated "SWIM test platform" hosted by Eurocontrol in Brétigny where SWIM-TI prototypes were delivered for internal verification before

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delivery to system projects. The SWIM Platform contained a WAN Emulator to reproduce as much as possible the PENS's SESAR VPN environment in use for SESAR validation exercises.

The project provided feedback on the SWIM TS and TAD through the multiple verification reports delivered after verification activities ([32], [54], [55]), the three Preliminary Solution Evaluations Reports ([61], [62], [63]), and during dedicated coordination meetings for the provision of early feedbacks.

The project has worked in close cooperation with the 'SWIM Exploitation' project for the preparation of the SWIM periodic demonstrations. The demonstration events organised in coordination with SJU and 'Information Management' Work Package expose SWIM results and improve the SWIM awareness all over the SESAR program.

A maintenance activity has been conducted for the duration of the project to assist system work packages in their use of the SWIM-TI prototypes, and update the project's deliverables.

Industry partners within the project provided support and maintenance to 'Validation Infrastructure Adaptation and Integration' Work Package with on-site support at their IBPs during SESAR validation exercises dry-runs and execution.

The project contributed to many SWIM-enabled SESAR solutions including "Initial SWIM" (#46) and "Initial ground-ground interoperability" (#28) solutions.

As of the project's contribution to the Master Plan **Error! Reference source not found.**, the project contributed to IS-0901-A (SWIM for Step1) which included the provision of the following capabilities:

- Ground-ground flight coordination and transfer functions between En-Route systems based on ED-133 flight object concept (ATC-to-ATC profile).
- Business-to-Business services to share traffic flow management information (including the capability to fill and validate flight plans) between the Regional NM / AM and APOC, FOC (CFMU/NOP B2B Profile).
- Business-to-Business services to share Aeronautical information between the EAD (as part of Regional NM / AM) and ER-APP-ATC, Airport Airside Operations, FOC/WOC (EAD B2B Profile).
- New information exchange standards.

The following table summarizes the project's contribution to the Technical Enablers from Dataset 15 [64].

Code	Name	Project contribution	Maturity at project start	Maturity at project end
ER APP ATC 160	ATC to ATC Flight Data Exchange Using Flight Object	The project has significantly contributed to this enabler; by delivering blue profile prototypes for inter-connecting ATC systems for multiple SESAR IOP validation exercises.	TRL 2	TRL 5
GGSWIM-10c	SWIM Supervision for Step3	The project has integrated first prototypes of local SWIM technical supervisions.	TRL 1	TRL 4
GGSWIM-51c	SWIM Ground-ground messaging services in Step3	The project has implemented and verified many requirements from both Yellow and Blue SWIM profiles.	TRL 1	TRL 6
GGSWIM-59c	SWIM security in Step3	The project has implemented and verified many security requirements from both Yellow and Blue SWIM	TRL 1	TRL 4

		profiles, and conducted some additional evaluations of security standards and products.		
SWIM-APS-05a	Provision and Consumption of Flight Object Sharing services for Step 1	The project has significantly contributed to this enabler; by delivering blue profile prototypes for inter-connecting ATC systems for multiple SESAR IOP validation exercises.	TRL 2	TRL 5
SWIM-APS-05b	Provision and Consumption of Flight Object Sharing services for Step 2	The project has significantly contributed to this enabler; by delivering blue profile prototypes for inter-connecting ATC systems for multiple SESAR IOP validation exercises.	TRL 2	TRL 5
SWIM-INFR-01a	High Criticality SWIM Services infrastructure Support and Connectivity	The project has implemented and verified many requirements from SWIM Blue profile.	TRL 2	TRL 6
SWIM-INFR-01b	High Criticality SWIM Services infrastructure Support and Connectivity	The project has implemented and verified many requirements from SWIM Blue profile.	TRL 1	TRL 6
SWIM-INFR-05a	General SWIM Services infrastructure Support and Connectivity	The project has implemented and verified many requirements from both Yellow and Blue SWIM profiles.	TRL 2	TRL 6
SWIM-INFR-05b	General SWIM Services infrastructure Support and Connectivity	The project has implemented and verified many requirements from both Yellow and Blue SWIM profiles.	TRL 2	TRL 6
SWIM-SUPT-01b	SWIM Supporting Registry	The project's V1.X prototypes integrated a (UDDI) registry; and many SWIM demonstrations and the SWIM Master Class used a design-time SWIM registry.	TRL 2	TRL 4
SWIM-SUPT-03a	SWIM Supporting Security Provisions	The project has implemented and verified many security requirements from both Yellow and Blue SWIM profiles, and conducted some additional evaluations of security standards and products.	TRL 2	TRL 4
SWIM-SUPT-03b	SWIM Supporting Security	The project has implemented and verified many security requirements from both Yellow and Blue SWIM profiles, and conducted some additional evaluations of security standards and products.	TRL 2	TRL 4

SWIM-SUPT-06b	SWIM Supporting Supervision	The project has integrated first prototypes of local SWIM technical supervisions.	TRL 1	TRL 2
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1.2 Project achievements

The project's first achievement was the provision of the "V1.x SWIM technical infrastructure definition" [12] document. A basis for the project's first prototypes delivered to industry IBPs for SESAR validation exercises.

The project focused on well-known mature inputs which shall definitively form part of the SWIM solution set to be in operation in step 1 and defined the following three SWIM profiles:

- ICOG / ED-133 (ATC-ATC En-route) - the rich peer-to-peer Flight Object (FO) exchanges to be prototyped in SESAR.
- CFMU/NOP B2B - a rich infrastructure and set of Web Services in operation in 2011 and further extended since.
- EAD B2B Web - in a similar manner to the NOP, the EAD had in operation in 2011 a rich infrastructure and set of web services.

ATC-ATC profile has matured to become part of the SWIM Blue Profile; while the CFMU/NOP B2B and EAD B2B profiles ended up part of the SWIM Yellow Profile.

The project has also provided the first SWIM ICD and proposed updates to the ED-133 WIRE-ICD[4] in a "SWIM interoperability guidelines" [30] document for better Interoperability between ATCs.

Other versions of the SWIM-TI prototypes taking into account the needs of SWIM-enabled validation exercises followed and were based on the SWIM TS.

The project has delivered SWIM-TI prototypes that have been used for the following SESAR solutions:

- #05: Extended Arrival Management (AMAN) horizon,
- #06: Controlled Time of Arrival (CTA) in Medium density / medium complexity environments,
- #33: Free routing for flights both in cruise and vertically-evolving above a specified flight level in low-to-medium density airspace,
- #28: Initial ground-ground interoperability,
- #33: Free routing for flights both in cruise and vertically-evolving above a specified flight level in low-to-medium density airspace,
- #34: Digital integrated briefing,
- #35: Meteorological Information Exchange, and
- #46: Initial SWIM

For efficient sharing of Flight Objects over PENS, the project succeeded in exchanging flight objects updates via multicast technology (SSM) as proposed in "WP1.3.1 Preliminary Solution Evaluations Report - V1" [61] and further prototyped by the DDS COTS vendors.

The project has also performed the following additional solution evaluations:

- Study of encapsulation of WS-Notification and SOAP services via AMQP as a means of transport between SWIM Nodes[61];

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- Analyse latest DDS Security standard and the use of Efficient XML Interchange format[62];
- Design and evaluation of inter-technology message bridging between AMQP and WS-Notification messaging brokers, and develop the concept of the Automatic Dependent Surveillance-Contract (ADS-C) Server using System Wide Information Management (SWIM) Technical Infrastructure[63].

The project has been promoting SWIM acceptance within the SESAR programme by organising SWIM demonstrations at Eurocontrol premises that gathered many operational and technical experts. It has organised or took part to the following events [46]:

- Organized three demonstration events in Brétigny in 2011, 2012, and
- Participated to the ATM World Congress 2013 in Madrid, and
- Attended the FAA mini-global as observers (Sept. 2014), and
- Attended the FAA mini-global II (April 2016), and
- Contributed to the SESAR SWIM Global Demonstration 2016 in Rome.

The project was involved in some additional programme level activities for the preparation of SESAR solution pack related to "Initial ground-ground interoperability" (#28), the definition of the SWIM compliance criteria, and participation to SWIM compliance assessment of Release 4 and Release 5 validation exercises.

1.3 Project Deliverables

The following table presents the relevant deliverables that have been produced by the project.

Reference	Title	Description
D03	V1.x SWIM technical infrastructure definition	This document provides the requirements for step1 for the Ground/Ground SWIM Technical Infrastructure. The requirements cover the Interoperability between ATCs and the description of the communications for the CFMU NOP B2B and EAD B2B.
D11	SWIM interoperability guidelines	This document expresses the technical interoperability constraints an application or a middleware product shall comply with in order to interoperate through the 'SWIM technical infrastructure' in the scope of SESAR Step 1.
D13	V1.1.0 verification report	This document is the verification report of the System Wide Information Management (SWIM) technical Infrastructure, for Step 1. More specifically, this document covers the verification of the version 1.1.0 of the SWIM Technical Infrastructure prototypes.
D14	V2.0.0 SWIM technical infrastructure definition	The purpose of this document is to provide the SWIM Technical Infrastructure Definition application to the SWIM-TI prototypes developed by the Frequentis, Thales and Indra in iteration 2.0.
D76	V2.0.0 verification report	This document is the verification report of the System Wide Information Management technical Infrastructure (SWIM-TI), prototyped in Step 2 –

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		iteration 2.0.0 - of the SESAR project 14.2.9. Verification exercises developed in the SWIM-TI V2.0.0 Verification Plan, are here refined into test procedures, and tested against the concerned SWIM-TI prototypes.
D69	Documentation maintenance delivery	This document is the maintenance report of the project's maintenance activity for SWIM-TI prototypes and related documentation. Software maintenance involves activities such as bug fixing, regression testing and delivery of software patches. Documentation maintenance activity includes upgrade of delivered documents.
D32	V3.0 SWIM technical infrastructure definition	The purpose of this document is to provide the SWIM Technical Infrastructure Definition application to the SWIM-TI prototypes developed by the Frequentis, Thales and Indra in iteration 3.0.
D36-002	V3.0.1 verification report	This document is the verification report of the System Wide Information Management technical Infrastructure (SWIM-TI), prototyped in Step 3 – iteration 3.0.1 - of the SESAR project 14.02.09. Verification exercises developed in the SWIM-TI V3.0.1 Verification Plan, are here refined into test procedures, and tested against the concerned SWIM-TI prototypes.
D42-005	SWIM Global Demonstration - 2016	This document reports the demonstration events to which the project has contributed and/or organized to expose its results and improve the SWIM awareness all over the SESAR program.
D84	WP1.3.1 Preliminary Solution Evaluations Report - V1	The document analyses the proposed architectural solutions and requirements for the 'FO Overlay Network' from TS/TAD 2.1 on existing [DDS] standards. It studies encapsulation of WS-Notification and SOAP services via AMQP as a means of transport between SWIM Nodes, and demonstrate a subset of the verification procedures as well as basic WS-Notification topic encapsulation, i.e. the subscription and consumption of notifications via AMQP.
D85	WP1.3.1 Preliminary Solution Evaluations Report - V2	The document reports on a prototypical implementation of DDS Security related requirements from TS/TAD 3.0. It studies moreover the use of the Efficient XML Interchange format.
D86	WP1.3.3 Preliminary Solution Evaluations Report - 2016	The document reports on the design and evaluation of an inter-technology message bridge between AMQP and WS-Notification messaging brokers, exploring the findings and experiences in bridging these two technologies, and it reports moreover on an optimization of the FO distribution in a PENS environment. It also presents and develops the concept of the Automatic Dependent Surveillance-Contract (ADS-C) Server using

1.4 Contribution to Standardisation

The project requirement verification activities and participation to SESAR validation exercises such as IOP Validation, contributed to the maturity of the SWIM Technical Architecture Document, SWIM-TI Technical Specifications, and SWIM Profiles Instantiations. It is expected that the SWIM TS, TAD and Profiles deliverables will be translated into EUROCONTROL standards as they are already "binding" at SESAR Deployment level.

The project particularly contributed to the following working groups:

- EUROCAE WG-59 ED-133 (Flight Object Interoperability Specification): The project's first prototype for IOP Validation raised and corrected many issues with the current ED-133 specification [30].
- EUROCAE WG-104 (AMAN SWIM Service): The project contributed to Basic XMAN V3 live Trials in Reims UAC which results will be used for the coming standard.
- SESAR IOP Analysis Team: The project is contributing to the SWIM part of the IOP specifications which will be used by the SESAR2020 IOP-related projects and will later feed EUROCAE WG-59 for the revision of ED-133.
- OMG DDS Security 1.0 FTF 2: The DDS (Data Distribution Service) middleware is used in the SESAR Blue Profile to distribute the Flight Objects between stakeholders. The project has contributed to the finalisation of the DDS security specification by raising 35 issues [62] to the OMG for correction in the DDS specification.

1.5 Project Conclusion and Recommendations

The project has delivered SWIM-TI prototypes that have enabled system work packages to validate SESAR operational concepts. The project's results in SWIM demonstrations have successfully contributed to demonstrate the benefits of improved sharing of network and flight information - both pre-flight and during flight execution within the SESAR program as well as to global partners ANSPs and Network Managers.

The project has contributed to the maturity of the SWIM Yellow Profile and Blue Profile specifications. The SWIM profiles will be handed over to the SESAR Deployment Programme as key input to AF5 - Initial SWIM (sub-AF 5.2 SWIM Infrastructure and profiles).

The project has also supported members from industry to develop pre-industrial SWIM-TI prototypes that contribute to the delivery of future SWIM-enabled systems and services.

The project recommends that further activities be tackled in the future to address other important areas that are necessary for SWIM deployment in Europe. These include the following:

- Civil/Military Connectivity (Green Profile),
- CyberSecurity,
- Performance and Scalability ,
- Service Life Cycle Management, and

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- Safety and support for Legal requirements

To ensure interoperability within European ATM, the project recommends whenever possible to put in place a Permanent SWIM Test Bed where service providers and consumers and also SWIM-TI implementers can test SWIM-compliance of their products and applications.

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